

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2016/2017

EME4096 - INTERNAL COMBUSTION ENGINES

(ME)

01 JUNE 2017
2:30 p.m. – 4:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages including cover page and appendices with 4 Questions only.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

A 3.0-liter SI V6 engine operates on a four-stroke cycle at 3600 RPM and has a compression ratio of 9.6. The engine is slightly over square with the bore and stroke being related as $S = 0.98B$ and the length of the connecting rod is 17.0 cm. At the specified engine speed, air enters the cylinders at 100 kPa and 65 °C, and the combustion process ends at 22° aTDC. The engine when connected to a dynamometer reads a brake output torque of 210 Nm. The engine is running with an air-fuel ratio of 18, a fuel heating value of 44,000 kJ/kg, a mechanical efficiency of 86%, and a combustion efficiency of 97%. At standard conditions, the air has a density of $\rho_a = 1.181 \text{ kg/m}^3$ and gas constant of $R = 0.287 \text{ kJ/kg-K}$.

Calculate:

- a) piston speed at the end of combustion, [8 marks]
- b) volume in the combustion chamber at the end of combustion, [4 marks]
- c) brake thermal efficiency, [7 marks]
- d) indicated thermal efficiency, [2 marks]
- e) volumetric efficiency, and [2 marks]
- f) brake specific fuel consumption. [2 marks]

Question 2

The compression ratio for a single cylinder engine operating on a dual cycle is 9. The maximum pressure in the cylinder is limited to 6000 kPa. The pressure and temperature of the air at the beginning of the cycle are 100 kPa and 30° C. Heat is added during constant pressure process up to 4 percent of the stroke volume. Assuming the cylinder diameter and stroke length as 250 mm and 300 mm respectively, determine

- a) temperature and pressure at all states in the cycle, [14 marks]
- b) air standard efficiency of the cycle, and [5 marks]
- c) the power developed if the number of working cycles are 3 cycles per second. [6 marks]

Take $c_p = 1.005 \text{ kJ/kg-K}$; $c_v = 0.718 \text{ kJ/kg-K}$; $k = c_p / c_v$; $R = c_p - c_v$.

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Question 3

- (a) In the compression ignition combustion, there are a series of events that, occur after the injection of fuel, list these events, and explain them briefly. [10 marks]
- (b) An engine runs on isooctane at an equivalent ratio of 0.833. Assume complete combustion,
- Write the balanced chemical reaction equation, [6 marks]
 - Calculate the air fuel ratio, [3 marks]
 - How much excess air is used, and [3 marks]
 - Determine the anti-knocking index (AKI) and fuel sensitivity (FS) of this fuel. [3 marks]

Question 4

- (a) A V 12, two-stroke compression ignition (CI) engine, produces brake power of 2440 kW at 550 RPM using stoichiometric light diesel fuel. The engine is square, has bore of 24 cm. Its volumetric efficiency, mechanical efficiency and combustion efficiency are 97%, 88%, and 98% respectively. The limit for the hydrocarbon emission index is 0.4 gm/kg of fuel, to avoid banning for the engine due to high pollution. Take the density of air $\rho = 1.181 \text{ kg/m}^3$. Calculate:
- The engine capacity in litres, [2 marks]
 - Indicated power of the engine, [2 marks]
 - Mass flow rate of injected fuel into the engine, [4 marks]
 - Mass of fuel unburned, [2 marks]
 - Specific emissions of hydrocarbons due to unburned fuel, and [2 marks]
 - Emissions index of hydrocarbons due to unburned fuel and comment on your answer. [2 marks]
- (b) In an engine working on diesel cycle inlet pressure and temperature are 1 bar and 17 °C respectively. Pressure at the end of adiabatic compression is 35 bar. The ratio of expansion after constant pressure heat addition is 6 and the cut-off ratio is 2.1. Take the specific heat ratio as 1.4, $C_v = 0.717 \text{ kJ/kg K}$, and $R = 0.287 \text{ kJ/kgK}$. Calculate:
- Compression ratio, [2 marks]
 - Maximum temperature in the cycle, [3 marks]
 - Heat added, [2 marks]
 - Heat rejected, and [2 marks]
 - The efficiency of the cycle. [2 marks]

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Appendices

Table 1: MOLECULAR WEIGHTS

SUBSTANCE		MOLECULAR WEIGHT (kg/kgmole) or (lbm/lbmole)
Air		28.97
Argon	Ar	39.95
Carbon	C	12.01
Carbon monoxide	CO	28.01
Carbon dioxide	CO ₂	44.01
Hydrogen	H ₂	2.02
Water vapor	H ₂ O	18.02
Helium	He	4.00
Nitrogen	N ₂	28.01

Table 2: PROPERTIES OF FUELS

Fuel		Molecular weight	Heating Value		Stoichiometric		Octane Number		Heat of Vaporization (kJ/kg)	Cetane Number
			HHV (kJ/kg)	LHV (kJ/kg)	(AF)s	(FA)s	MON	RON		
Gasoline	C ₈ H ₁₅	111	47300	43000	14.6	0.068	80-91	92-99	307	40-55
Light diesel	C _{12.3} H _{22.2}	170	44800	42500	14.5	0.069			270	35-50
Heavy diesel	C _{14.6} H _{24.8}	200	43800	41400	14.5	0.069			230	
Isooctane	C ₈ H ₁₈	114	47810	44300	15.1	0.066	100	100	290	
Methanol	CH ₃ OH	32	22540	20050	6.5	0.155	92	106	1147	
Ethanol	C ₂ H ₅ OH	46	29710	26950	9.0	0.111	89	107	873	
Methane	CH ₄	16	55260	49770	17.2	0.058	120	120	509	
Propane	C ₃ H ₈	44	50180	46190	15.7	0.064	97	112	426	
Nitromethane	CH ₃ NO ₂	61	12000	10920	1.7	0.588			623	
Heptane	C ₇ H ₁₆	100	48070	44560	15.2	0.066	0	0	316	
Cetane	C ₁₆ H ₃₄	226	47280	43980	15.0	0.066			292	100
Heptamethylnonane	C ₁₂ H ₃₄	178			15.9	0.063				15
α-methylnaphthalene	C ₁₁ H ₁₀	142			13.1	0.076				0
Carbon monoxide	CO	28	10100	10100	2.5	0.405				
Coal (carbon)	C	12	33800	33800	11.5	0.087				
Butene-1	C ₄ H ₈	56	48210	45040	14.8	0.068	80	99	390	
Triptane	C ₇ H ₁₆	100	47950	44440	15.2	0.066	101	112	288	
Isodecane	C ₁₀ H ₂₂	142	47590	44200	15.1	0.066	92	113		
Toluene	C ₇ H ₈	92	42500	40600	13.5	0.074	109	120	412	
Hydrogen	H ₂	2	141800	120000	34.5	0.029		90		

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Table 3: Thermodynamic Properties of Air

Temperature		c_p	c_v	$k = c_p/c_v$	Gas Constant $R = c_p - c_v$
K	°C	(kJ/kg-K)	(kJ/kg-K)		(kJ/kg-K)
273	0	1.004	0.717	1.40	0.287
298	25	1.005	0.718	1.40	0.287
300	27	1.005	0.718	1.40	0.287
500	227	1.029	0.742	1.39	0.287
850	577	1.108	0.821	1.35	0.287
1000	727	1.140	0.853	1.34	0.287
1500	1227	1.210	0.923	1.31	0.287
2000	1727	1.249	0.962	1.30	0.287
2500	2227	1.274	0.987	1.29	0.287
3000	2727	1.291	1.004	1.29	0.287

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